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Dated: September 11, 2007

Signature

(Raymond W. Augustin)

Docket No.: OSTEONICS 3.0-380
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Wang et al.

Application No.: 10/071,667

Group Art Unit: 3733

Filed: February 8, 2002

Examiner: R. R. Shaffer

For: POROUS METALLIC SCAFFOLD FOR
TISSUE INGROWTH

SUBSTITUTE APPEAL BRIEF

MS Appeal Brief - Patents
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

Applicants hereby file this brief on Appeal to appeal from the final rejection of claims 1-4, 6, 9-13, 15-18, 79, 82-87, 89-93, 95-98, and 101-103 mailed October 5, 2006.

REAL PARTY(IES) IN INTEREST

The real party in interest in this case is the assignee of record, Howmedica Osteonics Corp., 325 Corporate Drive, Mahwah, New Jersey 07430, as evidenced by the Assignments from Kathy Wang dated March 12, 2003 and recorded at reel 013926 frame 0646 and from Nicholas Dong and Michael Meehan dated June 27, 2002 recorded at reel 013464 frame 0685.

RELATED APPEALS AND INTERFERENCES

To the best of the current knowledge of Appellant, there are no related appeals or interferences pending before the United States Patent and Trademark Office regarding this United States Patent application.

STATUS OF CLAIMS

Claims 1-4, 6, 9-13, 15-18, 79, 82-87, 89-93, 95-98, and 101-103 are pending in the present application. Claims 1-4, 6, 9-13, 15-18, 79, 82-87, 89-93, 95-98 and 101-103 are rejected. Claims 5, 7, 8, 14, 19-78, 80, 81, 88, 94, 99 and 100 have been cancelled. Claims 1, 6, 82, 84-87, and 95 are being appealed. A clean copy of the appealed claims are attached hereto as Appendix A.

STATUS OF AMENDMENTS

The Amendment filed June 26, 2006 has been entered. An Amendment under 37 C.F.R. § 1.116 was filed on Jun 11, 2007 but was denied entry.

SUMMARY OF CLAIMED SUBJECT MATTER

The invention provides a porous metal scaffold for use in an implantable medical device comprising a porous metal network having pores defined by metal webs, the metal webs covered with at least one layer of metal particles bonded to the metal webs. Preferably, the metal webs of the porous metal scaffold may form a continuous inner skeleton. The pore size of the porous scaffold may be varied by bonding additional layers of metal particles to the at least one layer of particles. Also, changing a size of the metal particles may also vary the pore size of the porous scaffold. The metal foam is made by using a

polyurethane foam and coating it with metal by chemical vapor deposition (CVD).

Preferably, the bonding between the metal webs and the metal particles is accomplished by sintering the metal particles to the webs. Also, preferably, the metal webs have partially hollow cores. The hollow cores of the metal webs may be surrounded by an outer web wall that has openings therein. The openings in the web walls are formed when the polyurethane foam material is pyrolyzed and turned into a gas which escapes through the web wall by forming an opening therein.

The pore size of the porous scaffold may range from 100 μm to 1000 μm . The pore volume may range from 50% to 90%. The scaffold may be formed into a shape having a thickness of 0.5 mm to 5 mm.

Preferably, the porous metal scaffold is bonded to a solid metal substrate. Also, preferably, the porous metal scaffold is directly bonded to the solid metal substrate. The metal scaffold may be sintered to the solid metal substrate. The scaffold may include a plurality of pores having a size greater than about 100 μm . The metal particles may have a size of 20 to 100 μm and preferably from 40 μm to about 80 μm . The metal of the particles is preferably selected from the group consisting of titanium, titanium alloy, cobalt chrome alloy, niobium and tantalum. The web metal is also preferably selected consisting of titanium, titanium alloy, cobalt chrome alloy, niobium and tantalum. The metal substrate may be part of an orthopedic implant.

The application of metal particles involves applying one or more layers of metallic powder and binding it to the pre-sintered metal foam structure by powder metallurgy techniques.

To control the pore size of the final foam the number of applications of the titanium powder is varied, which powder is applied to thicken the green metal foam. The same goal may be accomplished by varying the particle size of the titanium powder. However, it should be understood that if the particle size of the powder is too large, the particles may not be able to penetrate into the pores of the metal foam.

In another illustrative non-limiting example, 1100 μm pore size polyurethane foam may require two powder layers to produce 600 μm pore size. Increasing the number of powder layers to three decrease the final metal pore size to approximately 400 μm , while applying only one layer of powder would result in final pore size of approximately 800 μm . The thickness and the required number of layers of the metal powder may be affected by the characteristics of the powder particle, such as average size, shape and particle size distribution.

Claims 1, 6, 82, 84-87, and 95 are being appealed.

Claim 1 relates to a porous biocompatible metal foam network having an open cell structure wherein the openings of each cell are formed by metal webs covered with at least one layer of metal particles disclosed in paragraph [0033]-[0039] of the application. At least some of the webs are covered with at least one layer of biocompatible metal particles having a size range between about 20 and about 100 micron as disclosed in paragraph [0112] of the application. The metal particles are bonded to the metal webs as discussed in paragraphs [0114] and [0115] of the application. This is accomplished by vacuum sintering as discussed in paragraph [0131] of the application. The porous metal network has a pore size of 100 to 100 microns and preferably 300 to 500 μm as disclosed in paragraph [0029] of the application after sintering.

Claim 6 is similar to claim 1 as is supported by the specification as set forth in the paragraph immediately above, with the addition that the webs have partially hollow cores as discussed in paragraph [0018] of the application which hollow cores are surrounded by an outer web wall that has openings therein as discussed in [0107] of the application.

Claim 82 is directed to a metal scaffold for forming at least part of an implantable medical device as discussed in the abstract of the specification. The claim requires a porous biocompatible metal foam network having an open cell structure wherein the opening formed when a tissue contacting surface of the metal device as discussed in paragraphs [0023]-[0037] of the application. The claim contains the limitation that the metal webs are thicker on a side thereof (ID side) than a second side thereof (OD side) which is discussed in paragraphs [0103] and [0125] of the application.

Claim 84 requires at least one additional layer of metal particles be bonded to the first layer which is taught in paragraphs [0100] and [0101] of the application.

Claim 85 requires the metal particles to be between 20 micron and 100 micron in size. This is disclosed in paragraph [0028] of the application and also in paragraph [0114].

Claim 86 requires the web to have partially hollow cores. This is disclosed in paragraph [0018] of the application.

Claim 87 relates to the hollow cores having openings therein which is discussed in paragraph [0107]. Claim 95 relates to a porous metal scaffold having individual metal particles with a size of 40 microns to about 80 microns. This

size range is disclosed in paragraph [0028] and [0114] of the specification.

GROUND OF REJECTION TO BE REVIEWED ON APPEAL

1. Whether claims 1, 6, 82, 84-87, and 95 are anticipated by Kaplan U.S. Patent No. 5,282,861 under 35 U.S.C. § 102(b).

ARGUMENT

1. The rejection of claims 1, 6, 82, 84-87, and 95 under 35 U.S.C. § 102 over U.S. Patent No. 5,282,861 (Kaplan) assigned to Ultramet. The Examiner rejects all the claims as anticipated by the Kaplan reference apparently by assuming that the chemical vapor deposition (CVD) process taught therein results in the same structure as claimed. Appellant wishes to point out that a chemical vapor deposition process uses vaporized metal for coating a substrate. The process involves depositing a solid material from a gaseous phase which results in a coating usually only a few microns thick. The Kaplan reference merely refers to the coatings as "thin films". The chemical vapor deposition process is not a line of sight process and therefore the vapor surrounds the webs and deposits the coating uniformly. The deposit of the metal is in the form of molecules of metal thereby forming a film which Ultramet (the assignee of the Kaplan patent) refers to on their web site (copy attached for background purposes only) as the nanolayering at a rate of 100 to 400 microns per hour.

A. The rejection of Claim 1 Under 35 U.S.C. § 102 (over Kaplan). Claim 1 of the instant application distinguishes over the structure of Kaplan in that the metal webs as discussed in [0090] are formed by Low Temperature Arc Vapor Deposition (LTAVD) and are covered by at least one layer of metal particles

having a size range of between about 20 and 100 microns. This structure is similar to that formed by Kaplan with the CVD process. There are no particles utilized in Kaplan having a size greater than vaporized metal molecules as discussed in Appendix B which are able to only form a nanolayer inherent in vapor deposition. It can be seen that the particles claimed herein are a significant percentage of the desired pore size such that at least are one additional layers of particles may be sintered to the claimed metal webs to reach the desired final pore size. It is Appellant's position that sintering, while a process step, results in particles which are sintered together to form a distinct structure. Sintering is defined as heating a metal powder which forms a coherent mass without melting. It is submitted that sintering is a term of art used in powder metallurgy for describing a structure formed by the welding together and growth of a contact area between two or more initially distinct particles at temperatures below their melting point but above 1/2 of the melting point (in Kelvins). Thus, the term bonding vacuum sintering inherently claims a structure of sintered particles (bonded but not melted together) formed by the sintering process which structure, in combination with the metal webs, distinguishes over the structure of Kaplan. Kaplan has no particles bonded to the CVD metal webs.

B. The rejection of claim 6 under 35 U.S.C. § 102 over Kaplan. With regard to claim 6, Appellant has claimed that the metal webs are partially hollow with their hollow cores surrounded by metal webs with an outer web wall that has openings therein. This structure is not anticipated by Kaplan which does not have hollow web walls since, as taught therein, the metal is chemically vapor deposited on a carbon structure which is solid. At the top of column 8 of Kaplan it states that FIG. 3 shows that each ligament is formed by a carbon core 104

covered by a thin film 106 of metal. The metal being deposited by CVD on the solid cores of Kaplan does not have openings therein but is solid as shown in the application and discussed in the process of depositing vapor on all sides of the carbon core. It should be noted that at the top of column 3 of Kaplan it states the disadvantages of using powder metallurgy to form a porous structure because some porous metallic materials, such as porous sintered powder-metallurgy materials, do not match the structure of cancellous bone sufficiently well to ensure successful ingrowth and integration. Although an obviousness rejection has not been made, this clearly teaches away from Appellant's process. This disadvantage discussed in Kaplan has been overcome by Appellant's combination of metal webs formed by low temperature arc deposition covered by particles with the use of powder metallurgy to vary the pore size and roughen the surface.

C. The rejection of claim 82 under 35 U.S.C. § 102 over Kaplan. With regard to claim 82, that as taught in paragraphs [0104] and [0126] of the application, the internal and external web surfaces can have different web thicknesses. As taught in Example 1 [0126], the increased web thickness may be on the side which contacts the substrate. Such a structure would not occur in Kaplan because, as taught in the materials taken from the Ultramet website, a key advantage of the CVD process lies in the fact that the reactants used are gases thereby taking advantage of the many characteristics of gases one of which is that the CVD process is not a line of sight process so that the coatings deposited by CVD are conformable and near net shape. Thus, one would not obtain the claimed variation in thickness when using the process taught by Kaplan. There is no teaching in Kaplan of varying the thickness of the webs. Applicant's process is a line of sight processes to the webs are thicker on one side.

This is accomplished by deposition particles on one side of the claimed metal core. Note Kaplan has a carbon core so sintering to the core is not possible.

D. The rejection of claim 82 under 35 U.S.C. § 102 over Kaplan. Claim 84 is not anticipated by Kaplan since there is no second layer of particles bonded to the first layer to form the claimed thicker side of the web.

E. The rejection of claim 85 under 35 U.S.C. § 102 over Kaplan. The particle sizes claimed far exceed the size of the molecular vapor used in Kaplan and are therefore not anticipated.

F. The rejection of claim 85 under 35 U.S.C. § 102 over Kaplan. Kaplan has solid carbon cores and does not have partially hollow webs as claimed. This claimed structure is not anticipated.

G. The rejection of claim 87 under 35 U.S.C. § 102 over Kaplan. Kaplan has solid carbon cores and not hollow webs as claimed. Kaplan does not have webs with openings therein open to the hollow interiors.

H. The rejection of claim 95 under 35 U.S.C. § 102 over Kaplan. Kaplan teaches the use of molecular metal gases for CVD and not metal particles 40 μm to 80 μm in size. Thus the resilient structure as claimed is not anticipated by Kaplan.

CONCLUSION

Kaplan does not teach or suggest using powder metallurgy to vary the porosity of a metal web which is hollow and has openings therein (claims 6 and 86). Kaplan does not teach varying the web thickness from one side of the scaffold to the

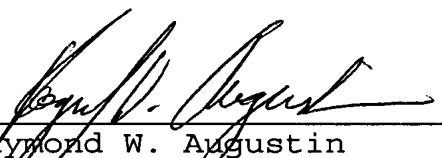
other as claimed in claim 82. Kaplan uses a molecular vapor and not metal particles in the much larger size range claimed.

It is Appellant's position that the claims under appeal are not anticipated by Kaplan's structure which inherently results from an entirely different process than Appellant's. Appellants have claimed these differences between their structure and Kaplan in independent claims 1, 6 and 82. Since the single prior art reference relied upon by the Examiner, as an anticipation, must teach each and every element of Appellant's claims is submitted that the Examiner has not filled his burden in showing where the claim structural of Appellant's claims is identical to that taught in Kaplan.

Therefore, Appellant requests that the final rejection of the claims be overturned.

Dated: September 11, 2007

Respectfully submitted,

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APPENDIX A - CLAIMS

1. A porous metal scaffold for use in an implantable medical device comprising:

a porous biocompatible metal foam network having an open cell structure wherein the openings of each cell are formed by metal webs, at least some of the webs covered with at least one layer of biocompatible metal particles having a size range between about 20 and about 100 μm , the metal particles being bonded to the metal webs wherein the bonding is accomplished by vacuum sintering the metal particles to said webs, the porous metal network having a pore size of 100 to 1000 μ for tissue ingrowth after sintering.

6. A porous metal scaffold for use in an implantable medical device comprising:

a biocompatible porous metal foam network having an open cell structure wherein the openings of each cell are formed by metal webs, at least some of the webs covered with at least one layer of biocompatible metal particles, the metal particles being bonded by vacuum sintering to the metal webs forming pores with a pore size of 100 to 1000 μ after sintering for tissue ingrowth wherein said webs have partially hollow cores wherein the hollow cores of said metal webs are surrounded by an outer web wall that has openings therein.

82. A porous metal scaffold forming at least a part of an implantable medical device comprising:

a porous biocompatible metal foam network having an open cell structure wherein the opening in each cell is surrounded by metal webs formed on a tissue contacting surface of the medical

device, the metal webs being thicker on a side thereof facing towards the tissue contacting surface, the webs covered with at least a first layer of biocompatible metal particles, the metal particles being bonded to the metal webs to produce a final cell opening size of between 100 and 1000 microns for tissue ingrowth.

84. The porous metal scaffold as set forth in claim 82 wherein at least one additional layer of metal particles is bonded to said first layer.

85. The porous metal scaffold as set forth in claim 82 wherein the size of the metal particles is between 20 μm and 100 μm .

86. The porous metal scaffold as set forth in claim 82 wherein said webs have partially hollow cores.

87. The porous metal scaffold as set forth in claim 86 wherein the hollow cores of said metal webs are surrounded by an outer web wall that has openings therein.

95. The porous metal scaffold of claim 82 wherein the individual metal particles have a size from 40 μm to about 80 μm .



APPENDIX B - EVIDENCE

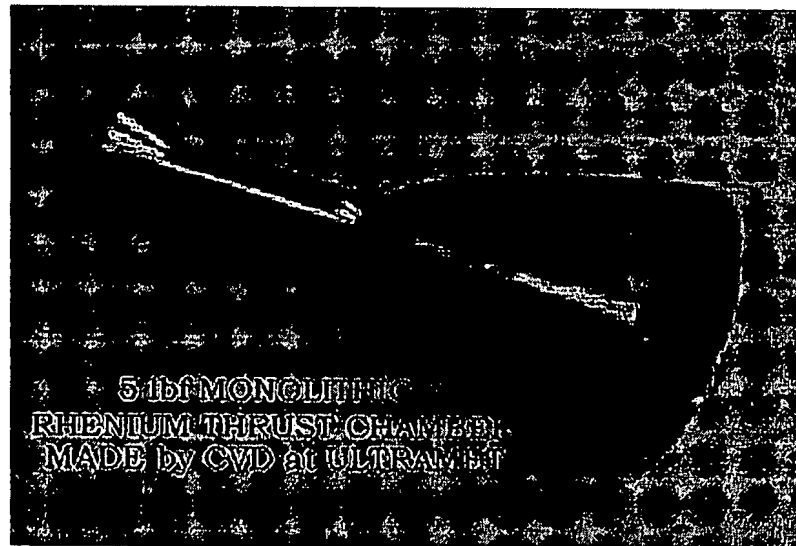
Home Page, Chemical Vapor Deposition (CVD),
<http://www.ultranet.com/4.htm>, June 7, 2007 and "Refractory
Ceramic Foams: A Novel New High Temperature Structure",
<http://www.ultranet.com/foamtech.htm>, June 7, 2007

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CHEMICAL VAPOR DEPOSITION (CVD)

Chemical vapor deposition (CVD) is a method of forming dense structural parts or coatings using the decomposition of relatively high vapor pressure gases. Gaseous compounds of the materials to be deposited are transported to a substrate surface where a thermal reaction/deposition occurs. Reaction byproducts are then exhausted out of the system.

CVD is a very versatile process used in the production of coatings, powders, fibers and monolithic parts. With CVD, it is possible to produce almost any metallic or non-metallic element, including carbon and silicon, as well as compounds such as carbides, nitrides, borides, oxides, intermetallics and many others. And applications are boundless.



A key advantage of the CVD process lies in the fact that the reactants used are gases, thereby taking advantage of the many characteristics of gases. One result is that CVD is not a line-of-sight process as are most other plating/coating processes. In addition to being able to penetrate porous bodies, blind holes, large L/D tubes, etc., CVD offers many advantages over other deposition processes. These include:

Versatile – can deposit any element or compound

High Purity – typically 99.99-99.999%

High Density – nearly 100% of theoretical

Material Formation well below the melting point

Coatings Deposited by CVD are conformal and near net shape

Economical in production, since many parts can be coated at the same

[HOME](#)

Refractory Ceramic Foams: A Novel New High Temperature Structure

Andrew J. Sherman, Robert H. Tuffias, and Richard B. Kaplan

Ultramet, Pacoima, CA

INTRODUCTION

Advanced aerospace and commercial applications are challenging materials suppliers to develop low-density composites with improved high-temperature performance. In response to this demand, Ultramet has developed a process that adds a new category to the conventional carbon-carbon, metal-matrix, and ceramic-ceramic high-temperature materials.

These new materials are termed refractory foams. Ultramet's research reveals that useful, lightweight refractory bodies can be produced by the chemical vapor infiltration (CVI) of an extremely porous vitreous carbon body with a refractory material or combination of materials. The density of the resultant body is purposely maintained at less than full density, resulting in a structure with enhanced mechanical properties.

FABRICATION

The use of cellular materials allows the simultaneous optimization of stiffness, strength, overall weight, thermal conductivity, surface area, and gas permeability. As such, these materials are highly desirable for a wide range of engineering applications. Cellular materials are the most efficient structure for many applications, and are the most common engineering material form in the natural world (e.g. wood and bone). Until recently, however, only wood was used to any great extent. Only during the twentieth century have man-made polymer foams been available for insulation, cushioning, padding, and packaging, but the high structural efficiency of cellular materials has been little used. A lack of engineering design familiarity with cellular materials, and a limited ability to tailor foams fabricated from engineering materials, have contributed to the lack of development of cellular structures.

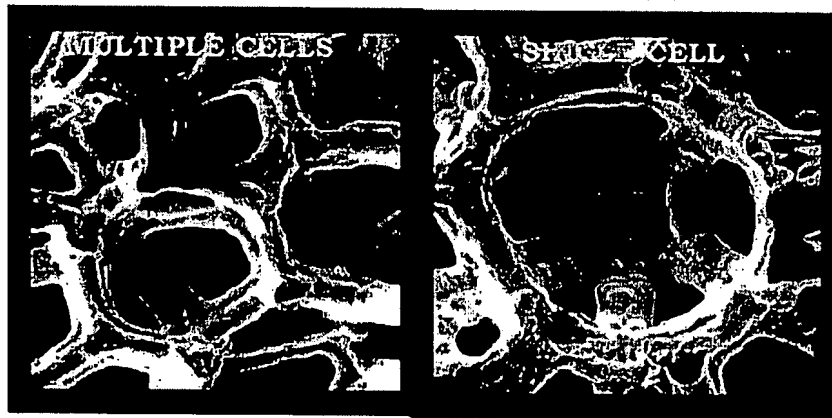
Techniques now exist for fabricating foams not only of polymers, but of metals, ceramics, and glasses as well. These newer foams are increasingly being used structurally, for insulation, and in systems for absorbing the kinetic energy of impacts. Their uses exploit the unique combination of properties offered by cellular solids, properties that ultimately derive from the cellular structure of the material.

Several techniques are used to produce engineering (structural) foams. With the exception of

syntactic foams and self-foamed materials such as foam glass, these materials are produced using a foamed polymer as the starting material. From these economical precursors, three processing routes have been established for the production of ceramic and metallic foams. Ceramic foams can be produced by dipping the polymer foam in a slurry containing an appropriate binder and ceramic phases, followed by pressureless sintering at elevated temperatures. A second process used to make metallic foams utilizes an electroless process for the deposition of a metal onto the polymer foam precursor via electrolytic deposition.

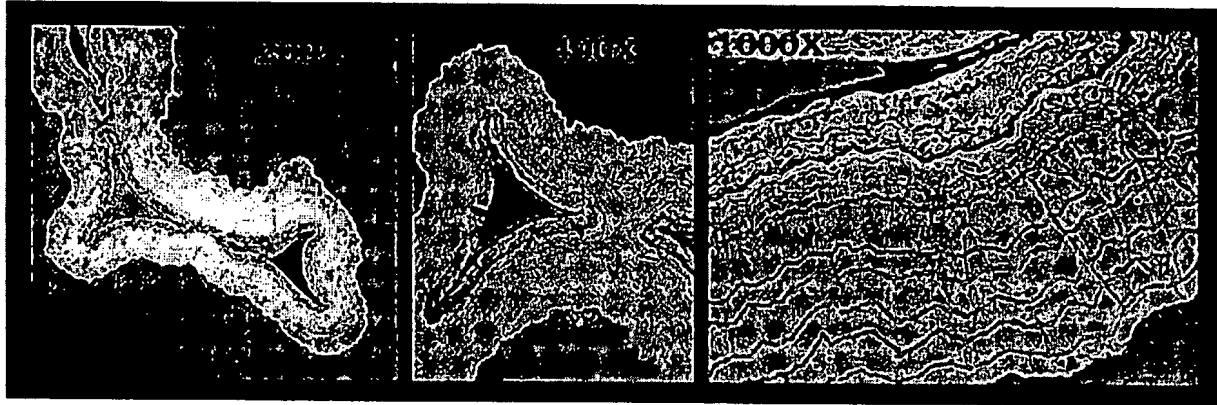
A third process, used exclusively at Ultramet, begins with the pyrolysis of the thermosetting polymer foam to obtain a carbonaceous foam skeleton. These carbonaceous foam materials are themselves attractive for many aerospace and industrial applications, including thermal insulation, impact absorption, catalyst support, and metal and gas filtration. They are thermally stable, low in weight and density, and are chemically pure; they have low thermal expansion, resist thermal stress and shock, and are relatively inexpensive. These Ultrafoam[®] materials are becoming readily available, can be furnished in various sizes and configurations, and are easy to machine, maintain and repair.

FOAM CELL STRUCTURE



Ultramet takes this process several steps farther by infiltrating the vitreous carbon Ultrafoam skeleton with refractory material(s) using CVD/CVI. In this process, 10-1000 microns of the desired refractory metal or ceramic are deposited onto the interior surfaces of the reticulated carbon foam. The structural integrity of the resultant refractory foam composite material (Ultrametal[®]) is greatly enhanced by the deposit, and the properties of the composite are dominated by the structure and properties of the deposit. The mechanical properties for a given material and density are often one to two orders of magnitude higher compared to slurry-cast materials because the CVD deposit is typically 100% dense with grain sizes less than 1-5 microns (although larger or smaller grains can be deposited) and <0.05% impurities.

The Ultramet process utilizes the high deposition rates of CVD (100-400 $\mu\text{m/hr}$) while depositing material within the foam structure via a combination of CVD and CVI techniques. The open-pore carbon foam precursor is heated to the temperature suitable for the desired deposition reaction, while the reactant gases are pulled through it. The gaseous precursor compound is reduced or decomposed at the foam surfaces, forming a uniform nanolayered deposit throughout the internal structure of the foam, with the nanolayering adding enhanced mechanical properties. The carbon lattice functions only as a substrate for the material being deposited.



It is important to note that the structural integrity of the fabricated foam composite is provided by the deposited thin films, rather than the carbon substrate. These films have much higher elastic moduli than the thin sections of vitreous carbon in the foam. Their high stiffness relative to the carbon results in their supporting the mechanical load for the entire body, ensuring that failure does not occur in the carbon. Because of the superior properties of the deposited films, the individual ligaments act as microcellular materials, with 70-100% of the strength being contributed by the deposit.

Refractory foams can be fabricated from any material or materials combination (either simultaneously deposited or layered) which can be deposited by CVD/CVI. Among the materials that can be deposited are the refractory metals (e.g. zirconium, niobium, hafnium, tantalum, tungsten, rhenum) and their ceramic compounds (e.g. the oxides, nitrides, carbides, borides, and silicides). Deposited material densities of up to 50% of theoretical values can be readily achieved. Stiffness, strength, thermal conductivity, and overall weight may be simultaneously optimized for a given application by varying the chosen deposited materials and their densities.

Structural applications often benefit from the low density, low thermal conductivity, and excellent thermal shock resistance of the foam composite, but require greater mechanical properties (flexural, tensile) than the basic Ultramet can provide. Flexural and tensile properties can be greatly enhanced if an adherent, continuous sheet is applied to the surfaces of the foam. Face sheets have been applied directly via CVD by changing process conditions and gas flow patterns to promote surface deposition, as well as by diffusion bonding, brazing, mechanical fasteners, and adhesives. The specific attachment method is determined by use conditions (e.g. temperature, stress, strain, environment, weight requirements) and can be optimized for strength, weight, adhesion, environmental resistance, etc. The applied face sheet (s) can be the same material as the foam, a totally different material, or a combination of both, as conditions require.

MECHANICAL PROPERTIES

The elastic properties at small deformation in foams can be calculated from the linear elastic bending of a beam of length l loaded at its midpoint for a regular square area of cells. In this manner, the relative density can be related to the Young's modulus, shear modulus, and Poisson's ratio respectively:

$$E^* = \frac{\sigma}{\epsilon} = \frac{C_1 E_s I}{l^4} \approx E_s \left(\frac{\rho^*}{\rho_s} \right)^2 \quad (1)$$

$$G^* = \frac{\tau}{\gamma} = \frac{C_2 E_s F}{l^4} \approx \frac{3}{8} E_s \left(\frac{\rho^*}{\rho_s} \right)^2 \quad (2)$$

$$\nu = \frac{C_1}{2C_2} \approx \frac{1}{3} \quad (3)$$

This analysis necessarily includes a number of approximations; for example, the way in which density is calculated double counts as the cell vertices, and the axial and shear displacements of the cell walls have been neglected.

A similar model results in equations for the elastic collapse strength, plastic collapse strength, and brittle fracture strength of foam materials. These relationships can be expressed as follows:

$$\text{For elastic collapse: } \sigma_{el}^* = .05 E_s \left(\frac{\rho^*}{\rho_s} \right)^2$$

$$\text{For plastic collapse in early stages: } \sigma_{pl}^* = .30 \sigma_{ys} \left(\frac{\rho^*}{\rho_s} \right)^{3/2}$$

$$\text{For plastic collapse, maximum tension: } \sigma_{pl_{max}}^* = \sigma_{ys} \left(\frac{\rho^*}{\rho_s} \right)$$

$$\text{For brittle crush strength: } \sigma_{cr}^* = .65 \sigma_{ts} \left(\frac{\rho^*}{\rho_s} \right)^{3/2}$$

$$\text{For fracture toughness (brittle fracture): } \frac{K_{Ic}}{\sigma_{ts} \sqrt{A}} = .65 \left(\frac{\rho^*}{\rho_s} \right)^{3/2}$$

Precise and accurate control over the physical properties of the resultant foam is easily attained, and may be optimized for a given application by varying the infiltration times in order to control the final density. An even greater degree of control may be attained by manipulating the pore size and shape of the cell geometry. By manipulating cell geometry in the carbon skeleton, properties may be optimized with respect to direction, the Poisson's ratio may be varied from -0.7 to 0.4, and the fracture toughness and impact resistance may be increased

over those of basic isotropic foams. Although modeling work is still required to account for the effect of varied cell geometry, the ability to manipulate geometry is extremely advantageous when producing sandwich components

APPLICATIONS

One application of this technology is in the fabrication of thermal insulation material. Preliminary measurements of zirconia refractory foam reveal that thermal insulation equivalent to that of the NASA space shuttle protective thermal tiles can be achieved at a 1000°F higher operating temperature. Using innovative techniques, Ultramet has fabricated insulation with a density gradient through the cross section of the material. This procedure makes it possible to blend a high-density surface with good mechanical properties into a region with low thermal conductivity. Other unique thermal structures may be created by depositing a structural material, such as niobium, on one portion of the cross-section and an insulator, such as zirconia or hafnia, on the opposite side.

Another potential application using this technology involves overcoating rhenium or niobium foam with iridium or platinum for lightweight, high-temperature oxidation-resistant structures. Ultramet also has produced boron carbide and silicon carbide foam structures that possess extremely high stiffness-to-weight characteristics. And using a SiC foam core composite panel, Ultramet has demonstrated a 60-80% weight savings over conventional carbon/phenolic and carbon/carbon heat shields for reentry protection. Additional stiffness-driven applications currently under study include lightweight nozzle flaps for advanced turbine engines and aerobraking structures, and aircraft wind and fuselage structures.

Applied to high temperature filtration problems these foam materials have seen service in air bags, solid rockets, and molten metal filtration. With the addition of a catalytic coating these foam materials serve as pollution control devices for unburned hydrocarbons and catalytic ignitors for rocket engines. In addition, when coated with a biocompatible material such as niobium or tantalum, these foam materials can be used for structural in-body implants to promote bone and tissue growth and also used for ex vivo three dimensional cell growth.

CONCLUSIONS

The flexibility of CVD permits the fabrication of a large number of materials in various geometric forms, one of which is the porous cellular structure. The fabrication of such a structure begins with the pyrolysis of a resin-impregnated thermosetting foam to obtain a reticulated carbon foam skeleton. The foam ligaments can then be coated with a variety of materials (metals, oxides, nitrides, carbides, borides, silicides, etc.), either singly or as hybrid, layered, alloyed, or graded structures. During this process, 10 to 1000 microns of the desired material(s) are deposited onto the foam ligaments by a CVI a variation of CVD. The thermomechanical properties of the resultant structure are dominated by the properties of the deposit, becoming independent of the carbon properties at very small material loadings. With precise control over the variables available, it is possible to obtain the simultaneous optimization of stiffness, strength, thermal conductivity, overall weight, and environmental resistance.

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HOME	FOAM	COMPOSITES	CATALYSTS	CVD	CONTACT US
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APPENDIX C - RELATED PROCEEDINGS

Appellant is not aware of any related proceedings.